Micro-plot scale overland flow generation and soil erosion in two recently burnt eucalypt stands in north-central Portugal:

measurement and modeling results for simulated and natural events

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1. Abstract

The work presented is being carried out in the framework of the EROSFIRE project, which, since late summer 2005, is investigating the hydrological and soil erosion response in six recently burnt eucalypt plantations. Field rainfall simulation experiments (RSE's) constitute the principal technique that is being employed by the EROSFIRE project for measuring soil erosion. Erosion plots are utilized as well but primarily to validate the results of the RSE's, in the sense of comparing erosion rates under artificial versus natural rainfall events as well as for micro-plots versus slope-scale plots. The various erosion measurements are ultimately intended to evaluate the suitability of selected erosion models for post-fire conditions.

The present paper will present initial results that, first and foremost, serve to illustrate the approach that is being applied and tested by the project. It will focus on the micro-plot scale data gathered for two neighbouring eucalypt stands during the first year following a wildfire in early July 2005, and on the results obtained with the MEFIDIS model.

The RSE's at both sites produced high runoff coefficients in September 2005 (median values of 70-80 %), which then tended to decrease with time after fire. Whilst sediment losses produced by the RSE's also tended to decrease with time, their most conspicuous aspect was the strong contrast between a few high (80-100 g/m2) and mostly low values (< 20 g/m2). These high values were restricted to the first two field campaigns in September and November 2005.

The erosion plots also revealed a noticeable temporal variation in runoff and erosion, with a clear suggestion of the role therein of soil water repellency. Overall differences between the two sites, on the other hand, are relatively minor, with median runoff coefficients over the entire 12-month period of about 25 % and corresponding sediment losses of 50-55 g/m2.

Initial MEFIDIS results for the RSE's as well as concurrent natural events are encouraging but require further work with respect to soil losses in particular.

2. Introduction

The EROSFIRE project wants to evaluate the suitability of rainfall simulation experiments (RSE's) to assess and model soil erosion hazard in recently burnt forest stands and, more specifically, commercial eucalypt plantations as the prevalent forest type on the north-central Portuguese hills and mountains. To this end, a total of six study sites were selected to carry out RSE's at various occasions following wildfire, on the one hand, and, on the other, to monitor runoff and erosion of bounded plots of the same dimensions as the RSE-plots (0.28 m^2) as well as of unbounded, slope-scale plots. MEFIDIS (Nunes et al. 2005) was chosen as the principal tool for modelling runoff and erosion under simulated and natural rainfall at the micro-plot scale, and for scaling up these results to individual hill slopes. Ultimately, slope-scale MEFIDIS results are to be evaluated against those of one or more, less complex models, in particular USLE (Universal Soil Loss Equation; Wischmeier 1978 for having been applied for the nation-wide map entitled "Soil losses after the forest fires of the summer of 2003". As final goal, the project envisages that the best model will be used in a computer application that allows mapping soil erosion hazard after forest fires, including for various post-fire intervention scenarios. By incorporating erosion mitigation and control measures, the software tool is hoped ultimately to contribute to a sustainable management of Portugal's widespread forest areas.

The present paper will focus on the results at the micro-plot scale under natural as well as simulated rainfall during the first year after fire, addressing field measurements as well as preliminary MEFIDIS results.

3. Study area & Methods

Towards the end of the summer of 2005, two slope sections were selected as permanent study sites in the locality of Açores, on the borders of the Águeda and Albergaria-a-Velha municipalities (Figure 1), in an area that was burnt during early July 2005 by a wildfire that affected a total area of about 16 km^2. The complete consumption of the litter and herb cover, together with the partial consumption of the shrub layer and tree crowns, suggest that fire severity at both sites had been moderate (Shakesby and Doerr, 2006). The main difference between the stands is their pre-fire land management, one site having been ploughed in down slope direction (Açore2) and the other lacking evidence of mechanical ground operations (Açores1). Two other aspects that the two study sites have in common are their underlying geology, composed of Precambrian schist, and their short length, which is due to the intricate network of paths dissecting each of the three areas. During the study period the total rainfall amounted to 1140 mm, and maximum 30-minute rainfall intensity was, on average, 7.5 mm h^{-1} but exceeded 35 mm h^{-1} at one occasion during autumn 2005.

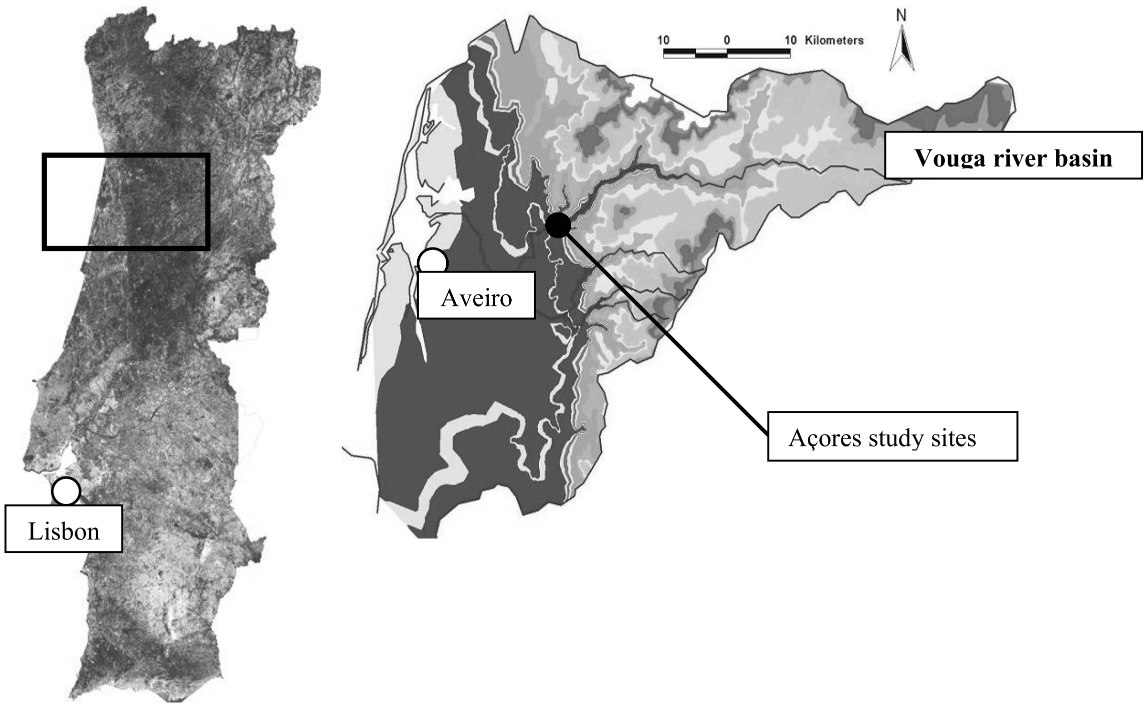

Figure 1 Localization of study area

Between September 2005 and July 2006, a total of 32 RSE's were carried out using a portable simulator following the Cerdà et al. (1997) design and square plots approximately 0.25m^{-2}. This was done in four field campaigns, each campaign involving two pairs of RSE's at each site, and each pair involving a high (40-45 mm h^{-1}) and an extreme intensity (80-85 mm h^{-1}) experiment on two adjacent plots. In between these two plots, a third was placed for sampling the initial conditions. The RSE's initially involved mobile plots but, starting in November 2005, involved fixed plots. The RSE's were carried out using a pre-established protocol, involving e.g. 60 min experiments, runoff measurements at 1-minute intervals, and collection of five runoff samples for laboratory analysis of sediment and organic matter concentration.

During the second half of September 2005, both sites were equipped with two pairs of neighbouring micro-plots of the same dimensions as the RSE-plots. The 30-l tanks connected to the plot outlets were then measured and sampled at weekly intervals till early October 2006. The study sites were monitored at about 2-weekly intervals as described Keizer et al. (2008).

4. Results and discussion

Overall values

The overall runoff coefficients and sediment losses over the entire, 12-month study period are shown in Table 1. Neither under simulated nor under natural rainfall differences between the ploughed (Açores2) and unploughed (Açores1) are marked. Worth mentioning is that sediment losses under both conditions involve important organic matter components, in the order of 50 %. Whilst runoff coefficients under simulated rain are higher than those under natural rain - probably due to the elevated intensities of the RSE's – the opposite is true for sediment losses. This is likely due to the lower kinetic energy of the simulated rainfall when compared with natural precipitation of the same intensity.

Using the same simulator at an intensity of 50 mm h^{-1}, Ferreira et al. (2005) obtained similarly high runoff coefficients (40-80 %) in recently burnt pine stands in central Portugal. Sediment losses in Table 1, however, are clearly lower than those of Ferreira et al. (2005: 0.52-0.64 g m^{-2} mm^{-1}).

The overall runoff coefficients registered under natural rainfall exceed those reported earlier by Shakesby et al. (1996: 4-16%) for recently burnt eucalypt stands in a nearby area. These figures, however, concerned much larger plots (16 m^2 plots) and the second instead of the year after the fire. The current sediment losses, on the other hand, are lower than those found by Shakesby et al. (1996: 50-220 g m^{-2}). As a results, the specific sediment losses of circa 0.04 g m^{-2} mm^{-1} reported here are roughly five times lower that the lower threshold value found by Shakesby et al. (1994: 0.2-1 g m^{-2} mm^{-1}) for pine stands burnt less than one year before. The comparatively low sediment losses are probably related with the study sites' prior, intensive land use, involving at least two previous crop-rotation cycles of eucalypt and, in the case of the Açores2 site, down slope ploughing some 4-5 years prior to the 2005 fire. This is also suggested by the pronounced stone lag that appeared with the washing away of the ashes.

Table 1 Overall runoff coefficients and sediment losses of micro-plots under simulated and natural rain in a ploughed (Açores2) and an unploughed (Açores1) eucalypt stand during the first year following wildfire

		Açores1	Açores2
RSE´s (n=16/site)	Runoff coefficient (%)	52	44
	Sediment losses ($g.m^{-2}$)	13	16
	Sediment losses ($g.m^{-2}.mm^{-1}$)	0.012	0.015
	Total simulated rainfall (mm)	1040	
Natural rain (n=4/site)	Runoff coefficient (%)	23	25
	Sediment losses ($g.m^{-2}$)	49	55
	Sediment losses ($g.m^{-2}.mm^{-1}$)	0.042	0.048
	Total rainfall (mm)	1140	
	I-30 (mm/h)	7.5	

Temporal patterns

Under simulated as well as natural rainfall, runoff and erosion varied strongly throughout the study period. The overall tendency is that of a decline with time after fire. In the case of the monitoring plots, however, runoff increased again after the summer of 2006, providing a clear suggestion of the role of soil water repellency (Figure 1).

MEFIDIS results

Runoff predictions by MEFIDIS improve markedly if, in the case of strong to extreme topsoil water repellency, infiltration capacity is substantially reduced through the adjustment of the hydraulic conductivity model input parameter values in particular.

Model results always over-estimate soil erosion. This could be related with the absence of specific input variables for burnt areas (e.g. ash layer effect, high stone cover hidden below the ashes), the presence of important processes (e.g. soil water repellency) not accounted for by the model, or the low soil erosion taxes registered. Some lessons learned from model application include the need to take into account changing soil hydrological properties, such as soil water repellency temporal/spatial patterns, or incorporating the presence of the ash layer. Even so the model results are encouraging, especially with respect to runoff generation.

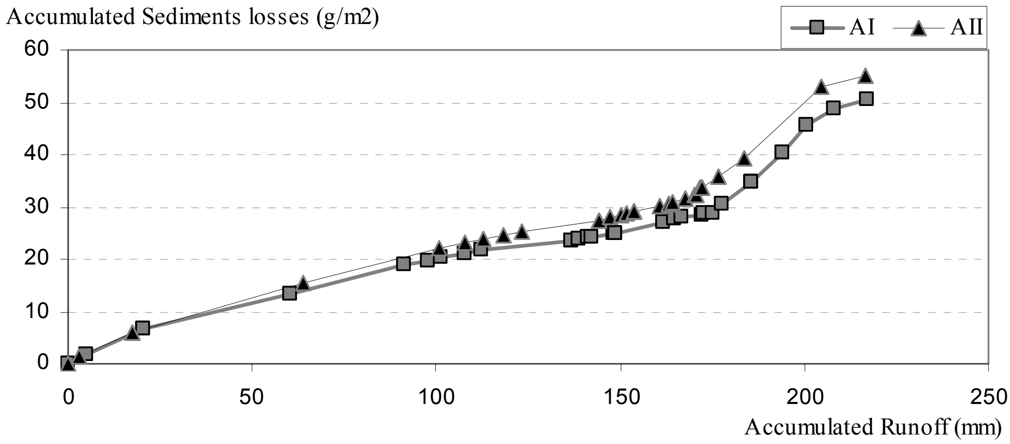

Figure 1 Cumulative sediment losses at the micro-plot scale under natural rainfall for a ploughed (A II = Açores2) and an unploughed (A I= Açores1) eucalypt stand during the first year following a wildfire

5. Acknowledgements

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